

## CHAPTER 11

### INDUSTRIAL HYGIENE, HEALTH PHYSICS, AND OCCUPATIONAL SAFETY

#### 11.1 INDUSTRIAL HYGIENE

##### 11.1.1 CHEMICAL SAFETY AND HAZARD COMMUNICATION

As ventilation systems control exposures to toxic and radiological materials, it follows that ventilation system filters may collect hazardous materials. In addition to exposure to the hazardous materials contained in the ventilation system or on filters, workers often are exposed to chemicals such as test aerosols when conducting testing.

Workers may be exposed to toxic chemicals by several routes such as inhalation, ingestion, contact with or absorption through the skin, and penetration of the skin via wounds. Chemicals may produce a variety of undesirable effects in the body including:

- Asphyxiation either by displacing oxygen (simple asphyxiation) or by interference with the body's ability to supply or utilize oxygen (chemical asphyxiation)
- Irritation
- Anesthesia
- Sensitization
- Reproductive toxicity
- Cancer
- Other toxic effects such as damage to the liver, kidneys, lungs, or blood cells

U.S. Occupational Safety and Health Administration (OSHA) standards (29 CFR 1910.1200<sup>17</sup>) require employers to implement a hazard communication program to inform workers about the risks associated with chemical

use. Employers are required to take the following steps to comply with the OSHA standards.

- Assess the potential hazards of materials used in the workplace.
- Prepare a written hazard communication program.
- Prepare and maintain a list of hazardous materials used in the workplace.
- Make material safety data sheets for each material available to employees.
- Train employees to recognize hazardous materials and use them safely. [The training must include specific information on chemicals and processes used in the workplace.]

Workers may consult material safety data sheets for information on hazardous materials such as components, possible toxic effects, other hazards such as fire and explosion, sources of additional information, and recommended control measures.

##### 11.1.2 NOISE

Noise can be a significant concern for personnel working on ventilation systems. Motors, fans, and other machinery along with airflow can create significant levels of sound. Even when workers shut down ventilation systems, equipment rooms often contain other sound sources.

Sound is produced when objects vibrate in a media capable of conducting sound. The vibration produces pressure variations that propagate through the media. Individual sounds are described using two characteristics—frequency and amplitude. Frequency is the rate (usually measured in cycles per second) at which complete cycles of high and low pressures are produced by

the sound source. Amplitude is the quantity of sound produced by a source or the quantity of sound available at a particular location. In general, sound can be classified into two types: steady-state sound and peak sound. Steady-state sounds are present over a period of time. Peak sounds are of shorter duration and must be measured with specific equipment. Sound-measuring instruments usually measure the root-mean-square of the pressure. The root-mean-square is a mathematical treatment that provides a more useful indication of sound levels.

Workers can be exposed to a wide range of sound pressures. For example, a sound pressure capable of causing pain is at least 1 million times the sound pressure considered to be the threshold of hearing. To cover this great range, sound pressure is expressed using the decibel scale, a logarithmic scale that compares the measured pressure to a reference pressure. The threshold of hearing is considered to be zero dB(A), and the threshold of pain is considered to be about 120 dB(A).

While sound can affect the human body in various ways, the most important is loss of hearing. Several types of hearing loss have been identified, but two are more important in the workplace. Conductive hearing loss occurs when sound pressure cannot reach the inner ear. This may happen because of a blockage of the ear canal, significant injury to the eardrum, or physical injury to the middle ear. In the workplace, such hearing loss is usually caused by extremely high peak noise levels such as an explosion or because of a traumatic injury to the ear. Sensorineural hearing loss is the inability of the ear to convert pressure variations into nervous impulses that the brain can interpret as sound. Sensorineural hearing loss can be caused by aging, infectious diseases, or exposure to some toxic chemicals. The most important workplace-related cause, however, is exposure to high levels of sound. Sound-induced hearing loss can happen gradually over a period of years, which makes the hearing loss difficult to detect. Another reason that this type of hearing loss is difficult to detect is that excessive sound usually causes hearing loss at some frequencies more than others. The person suffering from sensorineural hearing loss may be able to hear sounds such as speech, but may not be able to understand what is being said.

Excessive sound is best reduced with engineering controls such as vibration isolation and selection of quieter equipment. However, those who work with ventilation systems may need to use administrative controls and personal protective equipment. Administrative controls may involve changing work schedules to reduce the length of exposure and/or the number of workers exposed. This may include rotating employees' duties or work locations so that no employee receives a significant exposure. Another administrative control is scheduling sound-producing work during hours when fewer workers are around.

If engineering and administrative controls cannot completely reduce the sound to acceptable levels, then workers must use hearing protective devices to provide additional control. The ability of such devices to reduce sound levels is expressed as the Noise Reduction Rating (NRR). Those devices with a higher NRR are better at reducing sound levels. Many hearing protective devices are available. Specific devices should be selected based on several factors such as the NRR, comfort, and interference with other personal protective devices such as respirators. There are three common types of hearing protective devices: aural inserts, supraural protectors, and earmuffs. Aural insert protectors are commonly referred to as earplugs. They come in many shapes and sizes and are made from a variety of materials. Supraural protectors seal the opening of the ear canal. A light band holds a soft material in the opening of the ear canal. These devices are generally easier to insert and remove than earplugs and are easier to reuse. However, some workers may find such devices uncomfortable, and they may not provide as much sound reduction as earplugs. Earmuffs consist of two cup-shaped devices that fit over the entire external ear and seal against the side of the head. A spring-loaded headband holds the cups in place. Earmuffs are generally more durable than earplugs and are easy to use. However, to be effective, earmuffs must form a complete seal to the side of the head. Anything which interferes with the seal (e.g., earpieces of glasses, hair, respirators) may significantly reduce the effectiveness of the muffs. A relatively new kind of earmuff uses electronic devices to cancel the incoming sound. These muffs are quite expensive, but may be useful in some situations.

OSHA regulations require that employers implement a hearing conservation program for employees exposed to high levels of sound. This program includes sound measurements, training, record-keeping, and audiometric testing.

### 11.1.3 SHOCK-SENSITIVE MATERIALS

Laboratory personnel commonly use perchloric acid to prepare organic and inorganic materials for analysis. Perchloric acid is a strong oxidizing agent and reacts with many materials to form chemical compounds that are susceptible to detonation by heat, friction, or impact. The accumulation of such compounds in hoods, fans, and ducts presents a potentially hazardous situation for maintenance personnel and others who may be exposed to ventilation systems.

There have been several explosions and fires at U.S. Department of Energy (DOE) facilities caused by contact with perchlorates. The most serious occurrence (1962) killed one worker and injured two others during routine maintenance work. On several occasions at DOE sites, workers have had to stop activities when they found perchlorates in unexpected locations or at higher-than-expected levels.

Two articles in *Applied Occupational and Environmental Hygiene*<sup>18</sup> describe activities conducted at Oak Ridge National Laboratory (ORNL) to address potential perchlorate contamination of ventilation systems. A team of laboratory personnel, including chemists, industrial hygienists, and fire protection engineers implemented a program with the following objectives:

- Identify ventilation systems where laboratory personnel have or are now using perchlorates.
- Develop sampling and analysis protocols.
- Develop procedures for estimating the amount of perchlorate present in the samples
- Determine the threshold for what constitutes serious contamination.
- Generate a plan for decontamination of ventilation systems contaminated with perchlorates.

Identification of perchlorate contaminated ventilation systems may be difficult because some

systems have been in use for many years; laboratory personnel have used the systems for a variety of purposes; and former users may be difficult to contact. Laboratory personnel may use questionnaires to identify locations where perchlorates have been used. These questionnaires should be supplemented with visits to known current and former users. Laboratory records can also be useful in identifying perchloric acid usage.

The articles in *Applied Occupational and Environmental Hygiene*<sup>18</sup> describe a step-by-step process for decontaminating perchlorate-contaminated ventilation systems. The first step is containment of the contamination. Personnel should take precautions during sampling and dismantling operations to prevent the spread of contamination. This includes removing or protecting any equipment or furnishings which may be contaminated by a leak or spill. This is especially important when the ventilation system is radiologically contaminated. The second step is wetting. ORNL personnel used continuous wetting during aggressive penetration of a system such as sawing, drilling, or separation of rusted parts. The next step is testing. Safety and Health personnel should sample all ventilation systems with known usage of perchloric acid as well as a portion of systems without known usage. Industrial hygienists should select specific sampling locations within each ventilation system based on a determination of the likely point of accumulation and the feasibility of accessing the sampling location. ORNL personnel determined that, for most systems, samples should be taken at points in each system as close as possible to where air enters the duct work, within the fan housing, and at or near the exit from the stack. Due to the possibility of detonating perchlorates, sampling within a ventilation system may present a risk of injury to personnel (staff sample for perchlorates by swabbing about two square feet of surface with wetted gauze pads). Staff should minimize the number of samples, but should take enough to form a representative picture of perchlorate contamination. Maintenance personnel can provide valuable information on means of entry.

During the ORNL study, staff wore personal protective equipment such as ballistic-rated body shields during sampling activities. After examining the results of initial sampling, ORNL

staff determined that perchlorate salts often accumulated at the entrance to filter housings. Staff sampled fan housings by cutting a small incision in the fabric acoustical coupling between the duct and the fan, then sprayed the internal surfaces of the fan housing and fan blades with measured quantities of deionized water. They then collected the rinsate from the fan housing by suction.

The two articles cited above also describe methods for analyzing perchlorates. Analytical methods vary considerably regarding sensitivity and possible interferences. The articles state that a ventilation system is positive for perchlorates if rinsate is found to contain more than 750 mg of perchlorate per liter, or if swab samples indicate a perchlorate level of greater than 70 mg/m<sup>2</sup>.

The next step is removal of contaminated equipment, if feasible. Disassembly may make decontamination easier. The inside and outside of the ductwork should be wetted by spraying or misting. This wetting may wash some contamination from the system, but is done for safety rather than decontamination. ORNL personnel used nonsparking tools when sawing or cutting on ventilation systems. During drilling, they used a continuous flow of water over the drill bit.

Workers decontaminate ventilation system parts by soaking, if possible, followed by wet scrubbing. After washing, workers should test the parts for remaining contamination and further decontaminate as necessary. When decontamination is complete, the ventilation system parts may be repaired, replaced, or disposed of (ORNL staff caution that perchlorate contamination may be found outside as well as inside ventilation systems).<sup>15, 16</sup>

#### 11.1.4 HEAT STRESS

Workers may have to change or test filters without the aid of mechanical handling devices, and this work may be done in locations with little if any heat or air conditioning. In addition, the workers may wear personnel protective devices that increase the potential risk of heat stress.

The human body has a remarkable ability to regulate internal temperature within a narrow range, even when exposed to large fluctuations in

environmental conditions. Normal metabolic processes produce heat. The amount of heat produced is related to the level of physical activity. The body can also exchange heat with the environment by convection, radiation, or direct contact. The direction and magnitude of the exchange depend on the relative differences in temperature. The chief way of losing heat from the body is by sweat evaporation. The rate of evaporation depends on air temperature, air movement and relative humidity.

Heat stress can cause several problems. The first is simple discomfort, which is highly subjective and depends on factors such as type and amount of clothing worn, age, previous experience, and/or degree of acclimatization to heat. In addition to water, sweat contains sodium and other minerals. If a person loses too much sodium, they may suffer from painful muscle spasms (heat cramps). Excessive loss of water may also cause dehydration, which can lead to a condition known as heat exhaustion. A person suffering from heat exhaustion can maintain their body temperature within a reasonable range, but may become fatigued, or faint, or suffer from other symptoms. A person suffers heat stroke when the temperature regulation system is overwhelmed and the body temperature rises. The skin of someone suffering heat stroke is hot and dry. Heat stroke is a life-threatening condition, and the victim must get medical attention quickly. If allowed to continue, elevated body temperature may have serious consequences such as brain damage or death.

Portable fans, coolers, or other equipment may be helpful in removing heat and supplementing the body's ability to lose heat through evaporation of sweat. Control of heat stress greatly depends on replenishing body water. Workers can lose several kilograms of water during a workday. Workers should be provided with and be encouraged to drink water. Salted water or "sport drinks" may be useful in some situations (it is best to consult an occupational physician in such cases). Administrative controls may be used to reduce the risk of heat stress. The American Conference of Governmental Industrial Hygienists (2001 *Threshold Limit Values for Chemical Substances and Physical Agents*)<sup>19</sup> recommends a work/rest cycle to reduce the effects of heat stress. The relative

proportions of work and rest depend on the level of physical activity and environmental conditions.

### 11.1.5 CONFINED SPACES

Filter maintenance and testing may require work in or near confined spaces. Confined spaces may expose workers to hazards and may require additional training and planning before work is conducted. There are numerous examples of deaths or serious injuries that took place in a confined space. OSHA regulations require identification and posting of confined spaces, however, workers should be alert to unposted spaces.

A confined space is an area which meets the following three criteria:

- A person can bodily enter the space and perform assigned work.
- The space has limited or restricted means for entry and exit.
- The space is not designed for continuous human occupancy.

According to OSHA Standard 29 CFR 1910.146,<sup>20</sup> some confined spaces are called permit-required confined spaces. In addition to the above three criteria, permit-required confined spaces meet one or more of the following criteria:

- The space contains or has the potential to contain a hazardous atmosphere (this could include airborne toxic materials, flammable or explosive materials, or oxygen deficiency).
- The space contains a material with the potential for engulfment of an entrant.
- The space has a configuration such as a sloping floor that could trap an entrant.
- The space contains any other recognized serious safety or health hazard.

Workers should be aware that their work activities could introduce a hazard into a confined space, thereby redefining the space as a permit-required confined space. OSHA requires employers to implement a permit process for controlling entry into confined spaces. It is important to note that “entry” into a confined space happens when a worker places any part of their body into the space. The permit identifies hazards present in

the confined space, documents atmospheric testing, and lists who may enter the space and who is responsible for activities such as atmospheric testing, and rescue.

Before workers entry into and during work in a confined space, qualified personnel using properly calibrated and maintained equipment must conduct atmospheric testing. OSHA standards require testing for three types of airborne hazards before entry into a confined space.

- Oxygen content
- Concentration of flammable gases and vapors
- Concentration of toxic materials

If testing identifies atmospheric hazards, employers must institute controls such as ventilation or respiratory protection before entry. Planning for a confined space entry must include planning for emergencies. This planning is very important because a large portion of workers killed or injured in confined spaces are would-be rescuers. An emergency plan must include:

- Potential rescue methods
- Available rescue personnel
- Available and appropriate rescue equipment for the specific confined space
- Methods of summoning rescuers

During a confined space entry, at least one person, the attendant, must remain outside the space. This person may perform other duties such as air monitoring and providing assistance in handling materials and tools, but must maintain continuous communication with entrants and must not leave the area without obtaining a qualified replacement.

### 11.1.6 BIOLOGICAL HAZARDS

Biological hazards consist of bacteria, viruses, fungi, and, to a lesser degree, rickettsia and parasites. Some of these organisms may cause infections, and some may produce allergic reactions in susceptible persons. Ventilation systems may provide an environment that promotes the growth of bacterial and fungi. Workers should be on the lookout for signs of such environments (e.g., visibly moist areas or standing water, unusual odors). Respirators, protective clothing, and good sanitary practices

such as washing are effective means of reducing exposure to biological agents. Biological hazards may also include rodents, reptiles, insects, and arachnids.

## 11.2 HEALTH PHYSICS

Health Physics organizations are responsible for administering a radiation safety program that promotes the use of radiation and radioactive materials in a manner that protects workers, the public, and the environment. The uses of a Health Physics program cover a wide spectrum of activities across not only the DOE complex, but other areas as well. Humans are subjected to radiation every day because of natural radioactivity in the environment. Radiation is found in air, earth, water, foods, materials used to build homes, and even in the human body. Radiation and radioactive materials also are used in many ways that benefit humankind, including many diagnostic and therapeutic medical procedures, electricity production, in fire detectors, and food preservation, to name just a few. However, radioactive waste products are generated as a result of these beneficial uses of radioactive materials. These waste products can be in the form of solids, liquids, and gases, and disposing of them efficiently and effectively represents a great challenge.

This section is concerned with those radioactive waste materials contained in the process air streams that potentially could be released to the environment, the local work areas where workers could be exposed to radiation, and radiologically safe removal and replacement of the High Efficiency Particulate Air (HEPA) filter used to minimize potential releases and worker exposures. [This type of filter is usually supplemented by other filters such as the roughing filters that form part of the basic engineering design features of the air handling systems of a facility.]

Radiation safety is the responsibility of both the Health Physics program and the individuals on site. The steps and actions required to maintain occupational exposures at levels that are as low as reasonably achievable (ALARA) are described below. It is incumbent upon each individual working in a controlled area to understand these basic requirements and ensure they are considered when performing work that can result in exposure

to radiation. For example, each individual must know and understand the meanings of radiological postings, the radiation levels in the areas where they work, the training required to work in the area, and the importance of following procedures and abiding by the instructions in the procedures and in the Radiological Work Permit (RWP).

### 11.2.1 HEALTH PHYSICS CONSIDERATIONS FOR HEPA FILTER REMOVAL AND REPLACEMENT

DOE has regulations (10 CFR 835<sup>1</sup>) that require doses to workers and the public to be as low as possible. In addition to DOE regulations, U.S. Environmental Protection Agency promulgated in 40 CFR Part 61 also limit exposure of the public via the air pathway from DOE facilities. DOE policy on radiological health and safety is provided in DOE Policy 441.1<sup>2</sup> with further requirements for worker protection given in DOE Order 440.1A<sup>3</sup>. In addition, there are standards and guidance documents<sup>4-11</sup> that aid in interpretation and implementation of the regulations in 10 CFR 835,<sup>1</sup> from which much of the information in this section is derived. Some background material and some of the basic elements involved in radiation safety programs are discussed in the following sections. Although these elements are applicable to most tasks involving radiation and/or radioactive materials, the focus is on radiologically safe removal and replacement of HEPA filters.

#### ALARA

The regulations governing workers in the DOE complex contained in 10 CFR 835<sup>1</sup> mandate the documentation of a radiation protection program (RPP) that is approved by DOE. The content of the RPP is to be commensurate with the nature of the activities performed, but must include formal plans and provisions for applying the ALARA process. Giving due consideration to the economics of various activities, this means that all activities involving radiation or radioactive materials must be performed in a manner that maintains exposure to radiation at the lowest possible level. The formal plans for maintaining exposures at ALARA levels should include provisions for and descriptions of the following elements: